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**INFRA-RED LAMP PANEL STUDY AND
ASSESSMENT APPLICATION TO THERMAL VACUUM TESTING
OF SIGMA TELESCOPE**

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ABSTRACT

A Research and Development Program on the Infra-Red Test has been conducted by the CNES (French Space Agency) and developed by INTESPACE (a Subsidiary of CNES). A choice, after characterization, among several possibilities has been made on the type of methods and facilities for the I.R. test. An application to the Thermal Vacuum Test of SIGMA Telescope is described.

INTRODUCTION

The CNES (French Space Agency) built in 1970 a large space simulation in its TOULOUSE Center. This facility is managed by INTESPACE, a subsidiary of CNES.

Yet, the new launchers, Space Shuttle and Ariane, allow to design spacecraft with high masses and dimensions. So, two actions are developed :

- the increase of performance of the space simulator,
- the study of test technique for I.R. Thermal vacuum test.

The new capabilities of the space simulator are :

- a collimated solar beam of 3,8 m diameter,
- a gimbal of 2 degrees of freedom with 2,5 tons capacity,
- a control and command system which limits the test team for the facility at 3 people for shift.
- a measurement system with 450 T.C. Channels and 200 electric Channels.

A Research and Development Program has been decided by CNES and developed in cooperation with INTESPACE on the I.R. Test method and test facilities. This method has several advantages.

- to utilize the maximum dimension of T.V. Facility (our large chamber is 6.2 m diameter and 5.7 m height),

- to allow different fluxes on the faces of the test specimen, for example :
 - Earth albedo,
 - Emitted or reflected flux by Space Shuttle Cargo Bay.

These possibilities have been studied for some cases.

The object of this paper is the presentation of results of this study and its application for the test of SIGMA Satellite.

CHOICE OF I.R. FACILITIES

I.1 : SOURCES

Two types of I.R. lamps have been tested : 500 W and 112-125 V :

Research Inc. type 5236-5
 Philips type IRK C 536/98.

A set of 10 lamps have been characterized in the same conditions. The irradiance has been measured at 300 mm from the tube. The axis of the radiometer was normal to the tube and passing through its middle point. The results are :

	UNIT	PHILIPS	RESEARCH
Averaged irradiance	mW/cm ²	76,5	117,7
Estimated dispersion	%	6,05	12,8

Table 1 : irradiance of I.R. lamp

The research lamps have a metallic reflector, set behind the lamp. But for the Philips lamp, the reflector is a ceramic coating, on the quartz tube. This difference explains the different measured irradiance.

We have chosen Philips lamps for :

- the peak of irradiance in front of the lamp is less due to the type of reflector, so a good homogeneity is easier to obtain on a plane,
- the least dispersion of characteristics,
- its cheapest cost.

I.2 : CHARACTERISTICS OF SOURCES

I.2.1 : Irradiated spectrum.

A survey of facilities for this type of measurement has been made. But no

industrial hardware have been found for spectrum 0,4 μ m and 5 μ m wavelength. A French laboratory will perform these measurements this year for several color temperatures of the lamp.

1.2.2 : Spatial irradiance

Preliminary measurement have been made, but the requirements for the software dedicated for design of I.R. panels are measurements :

- at a fixed distance, in front of the lamp,
- along angle in the plane normal to the filament of the lamp,
- along in the plane of the filament normal to the reflector,
- versus input voltage.

The values are given in Table 2.

φ / θ	$f(\theta)$	$f(\varphi)$
0	1	1
10	0,9978	1,016
20	0,9632	1,023
30	0,8858	1,005
40	0,7679	0,9776
50	0,6080	0,9733
60	0,4306	0,9772
70	0,2587	0,952
80	0,103	0,850
90	0,014	0,588

Spatial flux intensity distribution, table 2

I.3 : POWER SUPPLY

We have tested two types of power supplied :

- distributed zero cross over firing circuit power supply,
- direct current power supply.

We have checked if they satisfy to the MIL-STD-1542 which is related to EMC-EMI. The first power supply does not meet the requirements it is due to the system which controls the zero cross over. But the Direct current power supply, has a defect in conducted mode for frequency below 500 Hz, but is good in radiated mode.

Although the first type is less in dimensions and cost, we have choosen the second type SODILEC SDR 150/10 which is or has :

- more safe to use,
- clear display of function parameters,

- IEEE programmable,
- very easy measurement of electric power supplied to the lamp,
- no variation of thermal flux on the specimen,
- good behaviour from a EMI-EMC point of view.

I - 4 : FLUX MEASUREMENTS

We have tested several radiometers :

- a Hy CAL radiometer type P 8400 water-cooled with a removable quartz window. But the sensitivity we have measured is 8 % greater than those given by the manufacturer. Our measures have been confirmed by the Intitut National of metrologie (French Bureau of Standards),
- a Medtherm radiometer type 64-02-16 no cooled without window. We have noted a discrepancy of 4 %, also confirmed. But the lack of thermal regulation does not allow its use in vacuum,
- a Medtherm radiometer type 64-02-20 water-cooled without window. Our measurement of sensitivity was in accordance with the manufacturer (2 % of error). We have noted that its response versus incident angle, is not good below with 60° where we have already 4% of error with the cosine law. The measured time constant is 3,1 s so the time to perform a measurement with an error less than 5% is 9,3 s minimum.

So to have good measurement of flux we have chosen this last type. But we think that it is not very interesting to generalize flux measurement in vacuum chamber like cartography because :

- the difficulty of this type of measurement (discrepancy between laboratory),
- the need of radiometer with thermal control (risk of water leak),
- response time is long,
- influence of the incident angle.

I - 5 : DESIGN OF LAMPS PANNEL

One problem is the design of lamps pannel to meet requirements on :

- flux intensity level,
- fluctuation of flux intensity level over the surface.

Europeen Space Agency has developped a softwave which can give a solution to this given problem. The IRSIM program computes (ref 2) the flux on the surface of the specimen and on the sensors when the user gives :

- a description of the test specimen by a set of surfaces,
- a set of infrared lamps,

- a system of baffles,
- a set of sensors.

We can adjust the level and the homogeneity of the flux by changing the lamp operating voltage and the position of the lamps.

The incident flux is calculated from the next data :

- the flux delivered by the lamp at 1 m distance directly in front of the lamp at the operating voltage,
- the distance from the lamp to the incident point,
- the spatial distribution of the flux intensity delivered by the lamp,
- the information if the incident point is or is not shadowed from the lamp and if the lamp is or is not baffled from a surface, the flux is calculated, with the assumption the intensity varies as the squared distance inverse.

ESA has given a copy of this software to the CNES so we made an evaluation.

The software is efficient but some additional possibilities would be useful :

- spherical surface for test specimen modeling,
- graphical output such flux curves along chosen axis or cartography of flux relative to an average flux.

The actual version is nevertheless very useful and we applied it to the design of the panel for the SIGMA test.

APPLICATION TO SIGMA TELESCOPE T/V TEST

2 - 1 : CONTEXT AND DESIGN GOALS

SIGMA is a Gamma Telescope ($\emptyset \sim 1.2$ m, $H_n^* \sim 3.5$ m, $M \sim 1000$ Kg), placed on an eccentric orbit (2000/200000 KM), 3 axis stabilized with telescope axis normal to Sun direction.

Thermal control is achieved with MLI all over the structure, and internal equipments thermally coupled with external VCHP radiator at opposite of Sun direction.

T/V tests could not be performed with solar simulator (unavailability of facility) and had to take place in Simdia facility (\emptyset 3 m, $L = 3$ m).

Telescope tube height had to be reduced from 3.5 m to 2.5 m, and solar fluxes simulated by I.R. means.

R.D. works in progress at that moment and SIGMA requirements gave the opportunity to evaluate I.R. simulation capabilities in a "real" case.

In accordance with SIGMA project management it was decided to build an I.R. simulator to achieve temperature field simulation on MLI surface. Development of this I.R. simulator had 3 steps :

- I.R. flux calibration in ambient air conditions (flux map),
- T/V qualification of I.R. simulator,
- T/V SIGMA telescope test.

2 - 2 : I.R. SIMULATOR SPECIFICATIONS

- To generate a well defined temperature field, as similar as possible to in-flight one, in view to have representative heat balance through MLI.
- To authorize various environment configuration (Hot case, cold case, no flux case...)
- To guarantee an error less than 10 % between measured and calculated flux density on a 90 % cylindrical sector, and between measured and the vertical ($k \cdot \cos \theta$) angular distribution.
- Not to illuminate shadowed surfaces.
- To be compatible with test facility mechanically (dimensions/fixation), thermally (no significant disturbances of heat sink temperature) and electrically (electrical power)
- To authorize precise and stable positioning of lamps with respect to illuminated surface.

* $H_n \sim 2,5$ m for STM model

2 - 3 : I.R. SIMULATOR DESCRIPTION

(See photo Fig. 1)

Mechanical structure is an aluminum grid with teflon isolating spacers for lamp fixation. A set of 49 "500 W Philips" lamps (cf. § I.1) is distributed (7 columns and 7 rows) on a 90° cylindrical surface at 30 cm distance from Ø 1200 telescope cylinder (see fig. 2).

Due to symetry it was natural to have one electrical power source for two lamps.

This power source was at regulated voltage (DC 0/120 V) (cf. § I.3) and voltage setting commanded by computer.

2 - 4 : AMBIENT AIR TEST

Ambient air tests were performed by means of a flux map device equipped with water cooled Medtherm radiometer (cf. § I.4) and connected with data acquisition/recording system. Voltage setting of each lamp couple was calculated by taking into account individual characteristics (couples determined after individual calibration).

Measurements gave us two flux map related to two typical flux values (1200 W/m² and 750 W/m²).

Results were studied on graphs (Flux variation along columns and along rows) and compared with IRSIM program results (See fig. 3 and 4).

Table N° 3 and 4 gives calculation/measurement discrepancies. We note that 10 % flux specification is achieved excepted in particular points and that errors are quite always underestimations in flux calculation.

Cosine law is respected in row distribution up to $\pm 37^\circ$ with an error less than 3 % and flux homogeneity along centry column is better than 8 % as for as 300 mm from ends.

2 - 5 : T/V QUALIFICATION OF I.R. SIMULATOR

(See photo fig. 5)

T/V qualification tests were performed in Simdia Chamber with a very simple model. This model had the same geometrical shape and thermal coating (Aluminized Kapton $\epsilon = 25 \mu m$) that SIGMA telescope.

This model was equipped with about 80 thermocouples.

Electrical configurations have been the same that these defined during Ambient Air Testing plus a "maximum hot case" to simulate a worst case (maximum coating aging) and other various "sensitivity" configurations (voltage variations on a lamp, a row, a column).

2 - 6 : T/V TELESCOPE TEST

Structural and Thermal Model (STM) was tested in Simdia Chamber with the two configurations ("cold case", "maximum hot case") defined during T/V Qualification tests of I.R. Simulator, and with a third configuration (zero I.R. flux).

Tests were performed in good accordance with procedure and previsions, without any problem related to I.R. simulation.

Temperature discrepancies which could have been noted, were induced by geometrical differency between first model (I.R. Qualification) and telescope STM (polygonal section instead of cylindrical, MLI thickness, cone angle between Ø 1200 - Ø 800 cylinders).

Test results made SIGMA thermal people able to evaluate temperature influence on MLI effectiveness, and to bring test temperature levels and test thermal exchanges nearer to "flight" estimations. So, if we consider alternate solution without any flux simulation, we obtain a reduction of differences between test heat leaks and flight heat leaks through MLI in the ratio of 4 (or more). In other respects temperature level differences (Flight-Tests) were reduced from 15° C to less 4° C.

CONCLUSION

Gradual approach was advisable and made the telescope tests performed without any major problem while we used a complete I.R. simulation set for the first time at INTESPACE and in a "R and D./Project joint venture".

During preparation and execution of these tests, encountered problems were :

- . Variation ($k \cdot \frac{1}{d^2}$) of incident power for a surface at a distance (d) from source makes source/surface positionning has to be very precise.
- . Dispersion of lamp characteristics requires individual calibration.
- . Influence of power voltage on emitted spectrum (and consequently on receiver absorption coefficient) induces on uncertainty.
- . Dues to the first problem hereover, geometrical irregularities and appendices have to be carefully evaluated.
- . Global efficiency (useful flux/electrical power) is rather low (25 %) for this type of cylindrical structure (with two different diameters). We need large electrical power and we have large heat load to evacuate through heat sink.

At this step of R. and D. action, we envisage to improve our knowledge of spectrum related to voltage and associated absorption coefficient for typical coatings. By another way we intend to develop automatic control and command of power supply.

REFERENCES

- 1) IRSIM : A Program for the calculation of infrared flux intensity incident spacecraft inside a test chamber, R.P. ROGERS ESA. SP - 100 (Intl. Symposium on Environmental and Thermal System for Space Vehicles. Toulouse, France, 4, 7 Oct. 1983).

Δ %	G6 (14°)	G7 (28°)	G8 (42°)	60°	70°
R1	0 %	- 0, 7 %	- 10, 7		
R2	+ 7, 3 %	- 0, 7 %	- 10, 6		
R3	- 0, 6 %	- 3, 8 %	- 14, 4	- 45, 7	- 74, 6
R4	- 2, 7 %	- 5, 9 %	- 17		
R5	+ 0, 6 %	- 2, 9 %	- 12, 9		
R6	+ 1, 9 %	- 2, 9 %	- 11, 3		
R7	- 1, 6 %	- 1, 7 %	- 12, 6	- 24, 2	- 55, 6

Table 3 - Verification of cosine law
Comparison measured/theoretical flux

Δ %	G5	G6	G7	G8
R1	- 8, 8 %	- 9 %	- 8, 5 %	- 4, 8 %
M12	- 7 %			
R 2	- 9, 9 %		- 7, 7 %	- 5, 4 %
M23	- 6, 2 %			
R3	- 5, 8 %	- 7, 2 %	- 8 %	- 5, 8 %
M34	+ 1, 4 %			
R4	- 2 %	- 2, 4 %	- 3, 1 %	0

Table 4 - Comparison measured/
computed flux by IRSIM

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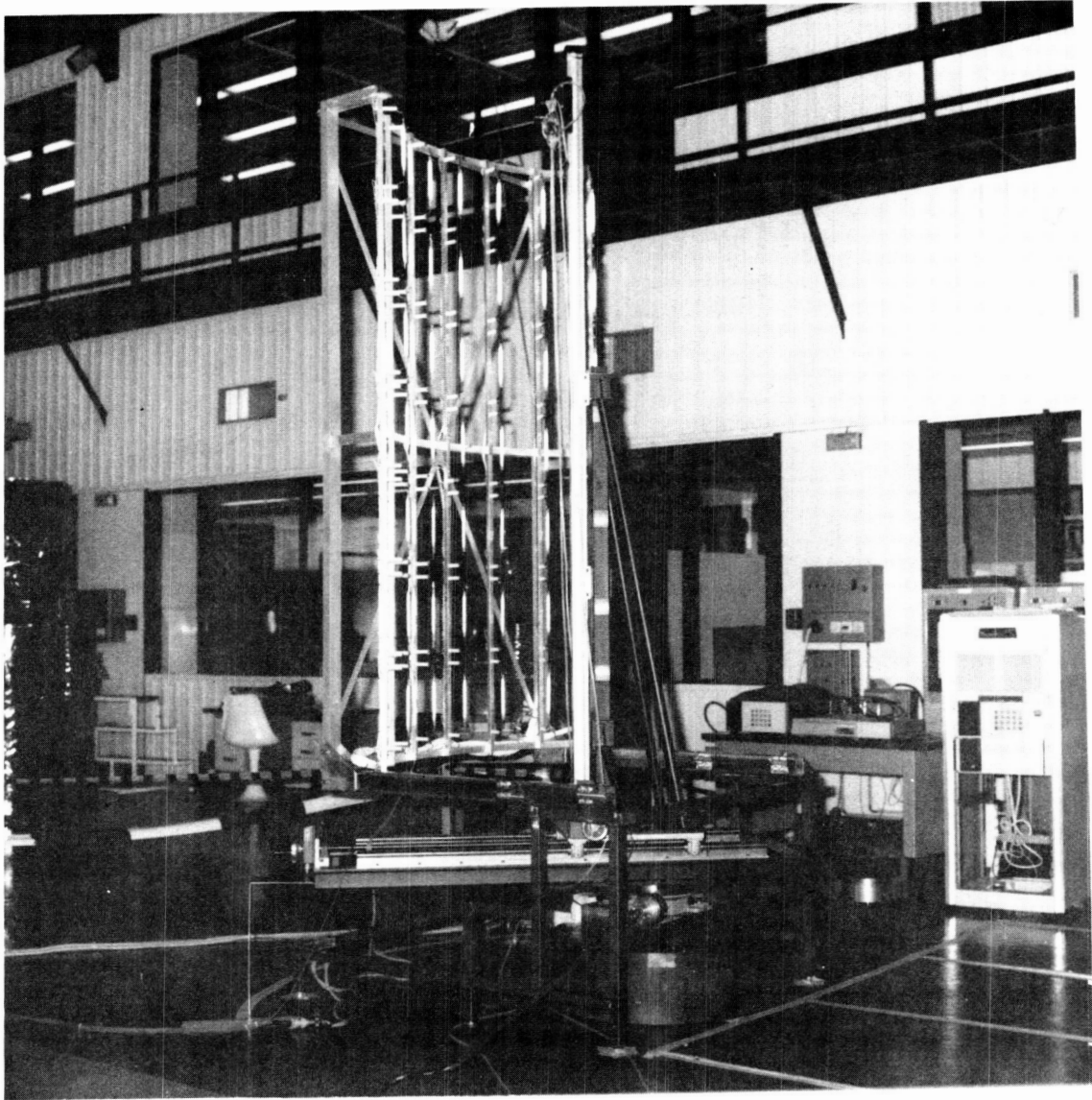


Fig. 1
I.R. Panel for Sigma Telescope
during flux cartography measurement

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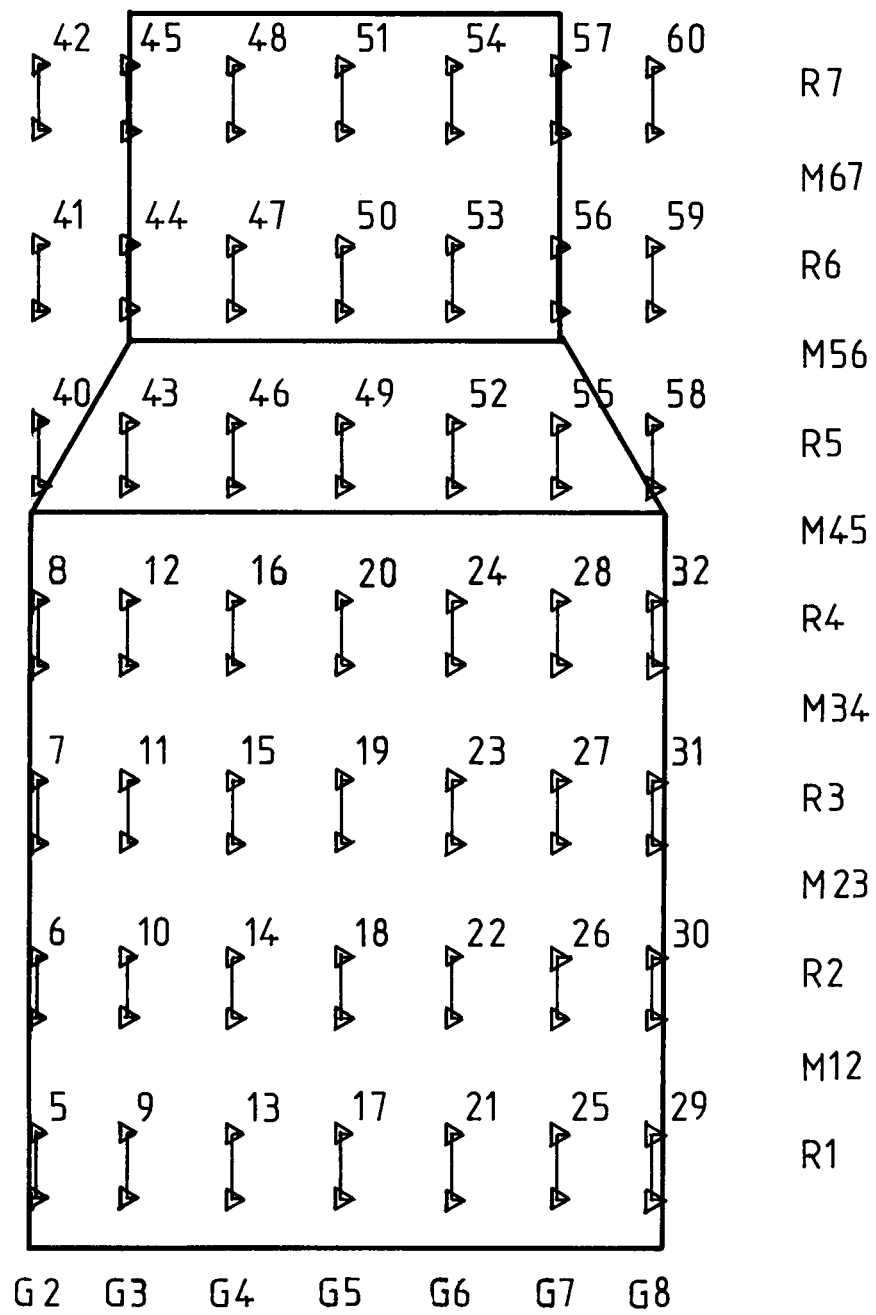


Fig. 2 : Set-up of I.R. lamps for the SIGMA Test

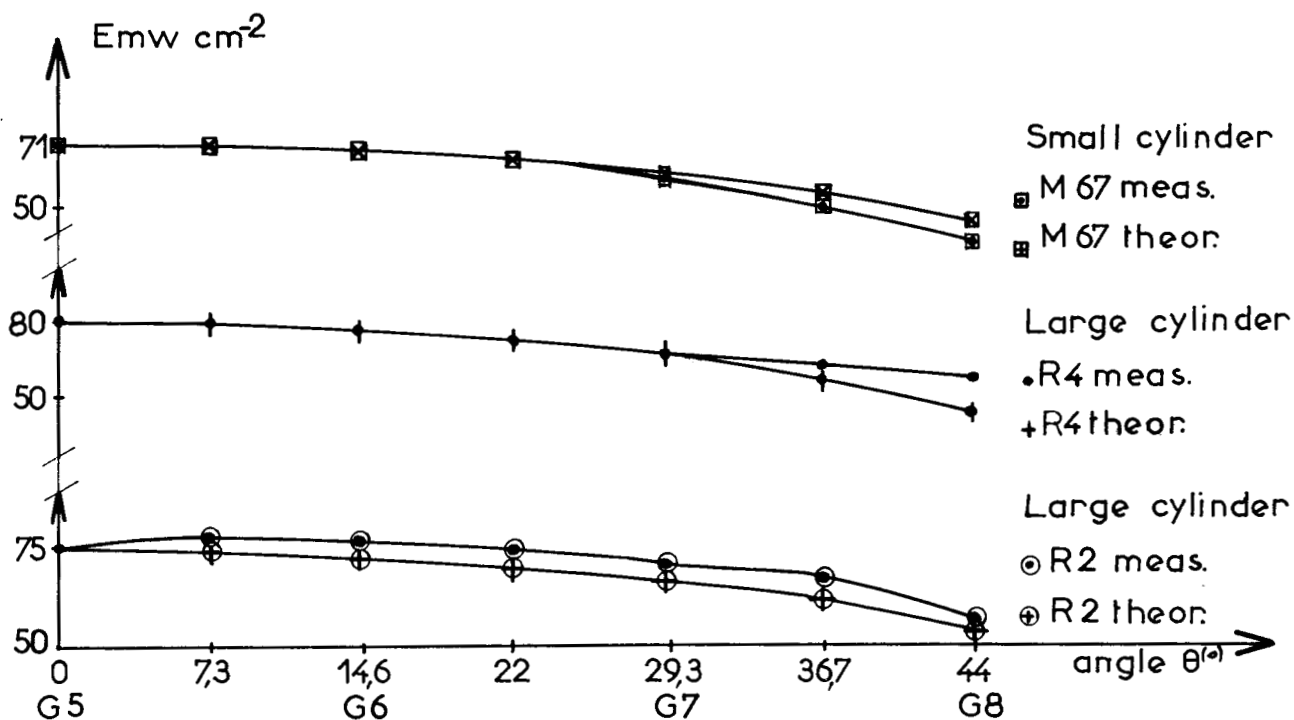


Fig. 3 : Verification of cosine-law (case 750 W.m^{-2})

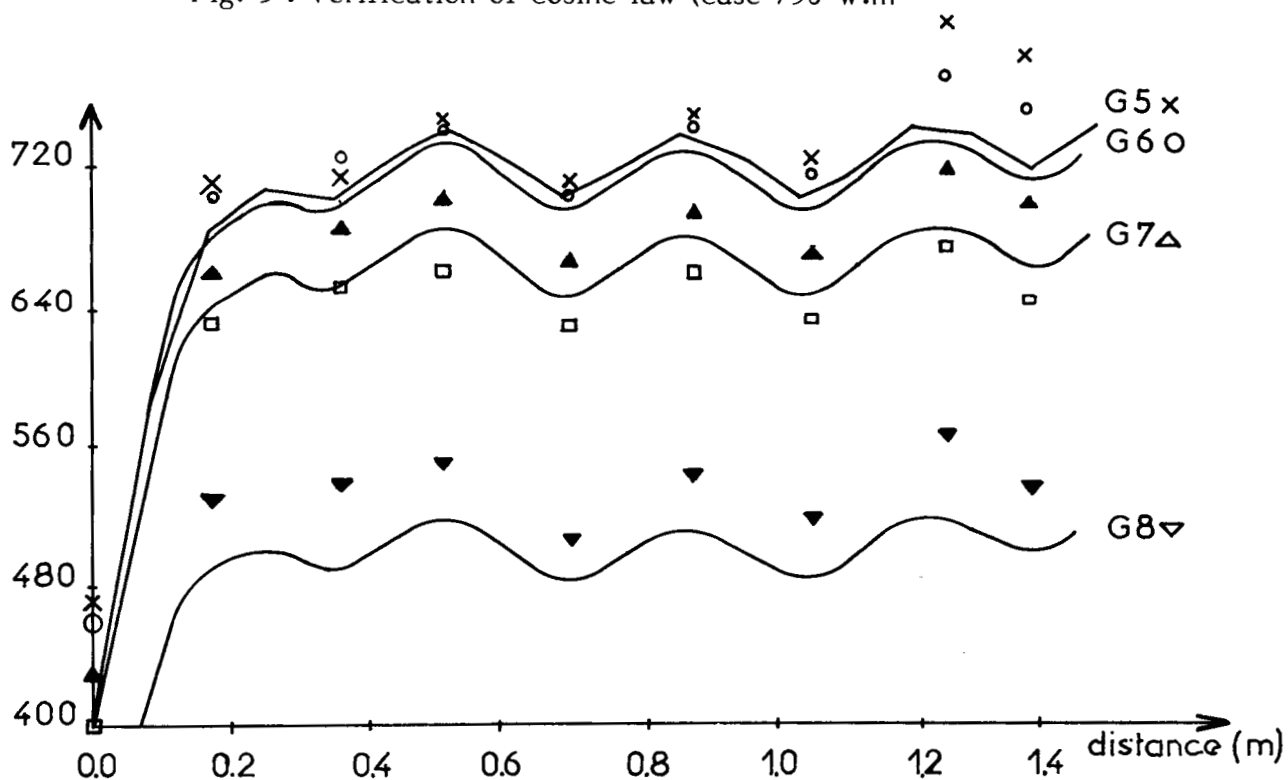


Fig. 4 : Comparison predicted/measured flux (case 750 W.m^{-2})

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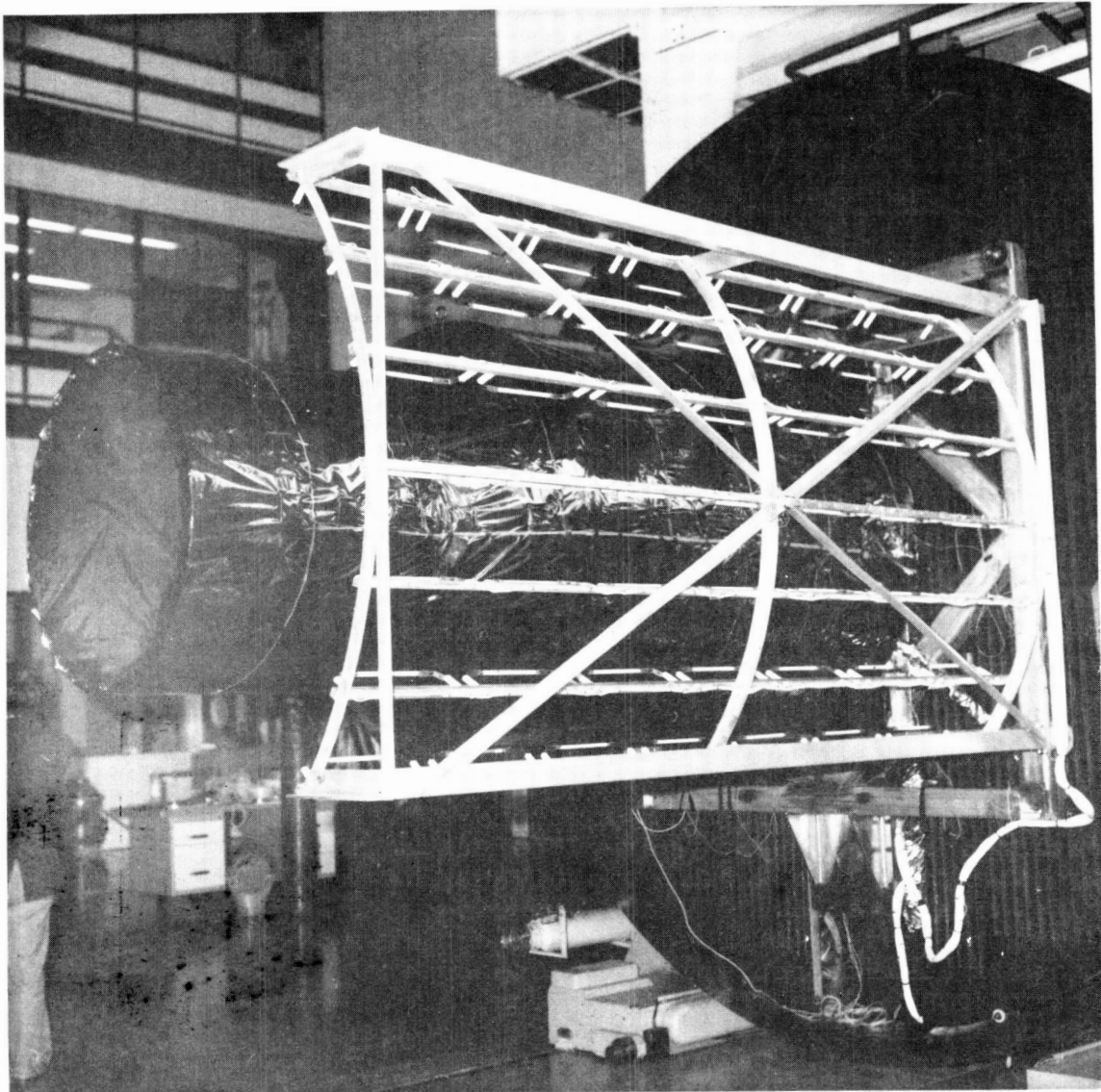


Fig. 5
I.R. lamp testing fixed on the door of
SIMDIA Thermal Vacuum Facility